

NO. 98-4061-3

INDEPENDENT STATE AUDITOR'S REPORT
ON THE MASSACHUSETTS HIGHWAY DEPARTMENT'S OVERSIGHT
OVER CERTAIN DESIGN ACTIVITIES RELATING TO THE
FORT POINT CHANNEL CROSSING IN SOUTH BOSTON
NOVEMBER 1, 1989 TO DECEMBER 31, 1999

TABLE OF CONTENTS/EXECUTIVE SUMMARY

Page**INTRODUCTION**

1

The Central Artery/Third Harbor Tunnel (CA/T) Project is a 7.5-mile interstate highway project designed to reduce traffic congestion in downtown Boston through the construction of an eight-to 10-lane underground Central Artery, a four-lane underwater tunnel that crosses Boston Harbor, and a South Boston bypass road, which serves commercial traffic. CA/T construction began in 1991 and is well underway in certain areas, including the South Boston Bypass Road, the Boston Marine Industrial Park, the tunnel crossing under Boston Harbor, the Bird Island Flats area of Logan International Airport in East Boston, and the Central Artery.

In 1987, the United States Congress passed the Surface Transportation and Uniform Relocation and Assistance Act, which made the CA/T Project eligible for a maximum of 90% federal reimbursement, depending upon the roadway classification and the availability of funds, with the Commonwealth bearing the remaining costs. In 1991, Congress passed the Intermodal Surface Transportation Efficiency Act (ISTEA) which extended the federal government's financial support of the project through 1997. In June 1998, Congress passed the new Transportation Equity Act for the 21st Century. Under this legislation, it is estimated that Massachusetts will receive an average of \$529 million per year for highway projects through fiscal year 2003. This amount of federal funding is approximately \$300 million less than the \$830 million average under the old ISTEA legislation and will affect the Commonwealth's percentage share of the remaining project costs.

In 1989 CA/T management estimated that the project would cost \$4.4 billion and would be completed in 1998. As of June 30, 1998, CA/T management estimated that the project would be completed by 2004 at a cost of \$10.8 billion. However, an earlier United States General Accounting Office (GAO) report, dated July 17, 1997, to the Subcommittee on Transportation, Committee on Appropriations, of the House of Representatives found that the cost of the project will exceed the Massachusetts Highway Department's (MHD) estimates and could reach as high as \$11.6 billion. The GAO report noted that the increase occurred primarily because of growth in the project's estimated construction costs. However, these costs were offset, in part, by future potential insurance savings. Further, the GAO report noted that MHD's cost containment goals envision a far better performance than has thus far been achieved and that the cost of completing the project could increase between \$100 million and \$500 million more if these goals are not achieved.

This interim report deals with MHD's oversight of the design activities and related additional costs associated with the Fort Point Channel Crossing in South Boston. To date, our ten interim reports have identified approximately \$288 million in unnecessary, excessive, and avoidable project costs.

TABLE OF CONTENTS/EXECUTIVE SUMMARY (Continued)

	<u>Page</u>
AUDIT RESULTS	6
<p><u>Inadequate Management Oversight over the Design of the Fort Point Channel Crossing Resulted in Additional Project Costs of More Than \$19 Million:</u> The design of the Fort Point Channel Crossing was affected by MHD’s inability to resolve the following two significant issues in a timely manner: the extended debate regarding the circular cofferdam preliminary design and the delay in resolving Ramp L design problems. Due to the significant increases in cost and schedule estimates associated with the temporary support of excavation, MHD established a Cost Recovery Committee (CRC) to determine whether any deficient performance had occurred. Although the CRC recommended that there was no reason to pursue cost recovery, several delays occurred. We estimated that the design delays increased construction costs by approximately \$13 million. In addition, the CA/T project incurred redesign costs of \$6.4 million.</p>	6
APPENDICES	
A. Central Artery/Tunnel Project – Map at Completion	19
B. Central Artery/Tunnel Project – Map of South Bay	20
C. Central Artery/Tunnel Project Photo – Fort Point Channel Looking East	21
D. Central Artery/Tunnel Project Photo – Overlooking Casting Basin	22
E. Central Artery/Tunnel Project Photo – Overlooking Fort Point Channel	23

INTRODUCTION

Background

The Central Artery/Tunnel (CA/T) Project is a major 7.5-mile interstate highway project designed to significantly reduce traffic congestion in the downtown Boston area through the construction of an eight- to 10-lane underground Central Artery, a four-lane underwater tunnel that crosses Boston Harbor, and a commercial traffic bypass road through South Boston.

In 1984, the Massachusetts Highway Department (MHD)¹ awarded to the joint venture of Bechtel/Parsons Brinckerhoff (B/PB) a management consultant contract to manage project design and construction activities. The value of this contract was \$1.8 billion as of November 1999. B/PB has overall responsibility for project design, management, and interface coordination of all construction contracts.

CA/T construction, which began in 1991, is well underway in certain project areas, including the South Boston Bypass Road, the Boston Marine Industrial Park, the tunnel crossing under Boston Harbor, the Bird Island Flats area of Logan International Airport in East Boston, and the Central Artery. This interim report deals with MHD's oversight of the design activities and the additional costs associated with the Fort Point Channel Crossing in South Boston.

In 1987, the United States Congress passed the Surface Transportation and Uniform Relocation and Assistance Act (STURA), which made the CA/T Project eligible for a maximum of 90% federal reimbursement, depending upon the roadway classification and the availability of funds, with the Commonwealth bearing the remaining costs. Later, in 1991, Congress passed the Intermodal Surface Transportation Efficiency Act (ISTEA), which extended the federal government's financial support of the

¹ The Massachusetts Turnpike Authority assumed ownership and management of the CA/T project under a state law enacted in March 1997. Because the activities discussed in this report occurred for the most part under MHD's jurisdiction, we have retained the use of the MHD designation.

project through 1997. In June 1998, Congress passed the new Transportation Equity Act for the 21st Century. Under this legislation, it is estimated that Massachusetts will receive an average of \$529 million per year for highway projects through fiscal year 2003. This amount of federal funding is approximately \$300 million less than the \$830 million average under the old ISTEA legislation and will affect the Commonwealth's percentage share of the remaining project costs.

In 1989, it was estimated that the project would be completed in 1998 at a cost of \$4.4 billion. As of June 30, 1998, CA/T management estimated that the project would be completed in 2004 at a cost of \$10.8 billion -- six years later than originally scheduled and 145% more expensive than the 1989 estimate.

However, an earlier United States General Accounting Office (GAO) report, dated July 17, 1997, to the Subcommittee on Transportation, Committee on Appropriations of the House of Representatives found that the cost of the project will exceed MHD's estimates and could reach as high as \$11.6 billion. The GAO report noted that the increase occurred primarily because of growth in the project's estimated construction costs. MHD had offset the estimated cost increases with potential project insurance savings that would not be realized until 2017 -- long after construction is completed. The GAO report also indicated that MHD's estimate was based on aggressive cost containment goals that, although commendable, envisioned a far better performance than had thus far been achieved. Moreover, the report noted that the cost of completing the project could increase between \$100 million and \$500 million more if these goals are not achieved.

This interim report deals with MHD's oversight of the design activities and related additional costs associated with the Fort Point Channel Crossing. To date, our interim reports have identified approximately \$288 million in unnecessary, excessive, and avoidable project costs. The project area and major contracts discussed in this report are briefly described below:

Fort Point Channel Crossing Project Area: The preliminary design of the Fort Point Channel Crossing, located in South Boston, involved the design and construction of two multi-lane highway tunnels

placed under active railroad tracks, over the Massachusetts Bay Transportation Authority's (MBTA) Red Line and in between the United States Postal Annex and the Gillette Company (see Appendix B). The construction included the fabrication and placement of concrete tunnel sections across Fort Point Channel. The size of the tunnel sections and the physical limitations of the area bridges prohibited off-site fabrication. As a result, a casting basin (temporary dry-dock) is to be built on the east side of Fort Point Channel (see Appendix D). The casting basin had a two-fold purpose: (1) to serve as a work area for constructing the tunnel sections and (2) to become part of the permanent cut-and-cover tunnel after placement of the tunnel sections in the channel. At the mouth of the casting basin a series of cofferdam cells is to be built to prevent channel water from entering the basin. When the tunnel sections are completed, a portion of the cofferdam will be breached, the casting basin flooded, and the tunnel sections floated into place in the channel. Concurrently, on the west side of Fort Point Channel, a series of cofferdam cells is to be constructed wherein the landward tunnel roadways and ramps will be connected to the immersed tunnel tubes. The preliminary cost estimate for construction of the Fort Point Channel Crossing was \$516 million, with a completion date of late 1998. Currently, the cost of construction for the redesigned crossing, referred to as the Extended Immersed Tunnel Tube scheme, is in excess of \$1.1 billion with a completion date of late 2001 (see Appendices C, D and E).

Major Design Contracts

I-93/I-90 Interchange: The I-90/I-93 Interchange design contract (D009A) was awarded to the joint venture of Maguire and Harris, the D009A Section Design Consultant (Maguire/Harris) on October 3, 1991 for \$24,005,011. A Notice to Proceed (NTP) was given on November 22, 1991. The design contract, originally scheduled to be completed December 31, 1998, is now scheduled to be completed on June 30, 2002. As of December 1999, the adjusted contract amount to complete the design is \$99,732,659.

The scope of the original D009A design contract included the final design of the I-90/I-93 interchange, including the I-90 mainline section and auxiliary tunnels, the I-93 northbound mainline section and auxiliary bridge and transition structures, the connecting I-90 and I-93 ramps, and a tunnel

ventilation building (Vent Building #1). Included in the scope of work is the design of a series of cofferdams, behind which the water and land tunnel sections for the Fort Point Channel Crossing would be connected.

On December 2, 1991, Maguire/Harris entered into a subcontract with Haley and Aldrich who would provide Maguire/Harris with geotechnical services for the D009A design contract. Haley and Aldrich was responsible for providing the geotechnical engineering support for the design of the temporary cofferdams. The original subcontract value was \$693,688. However, as of December 1999, the adjusted contract value was approximately \$6.9 million.

I-90 Fort Point Channel Crossing: The I-90 Fort Point Channel Crossing design contract (D009B) was awarded to the joint venture of Gannett-Fleming, the D009B Section Design Consultant on June 15, 1993 for \$20,129,686. The design contract's NTP was given on June 21, 1993, and is scheduled to be completed by December 31, 1999. As of December 1999, the adjusted contract amount to complete the design was \$47,999,686. The scope of the D009B design contract included the final design of the I-90 Fort Point Channel Crossing including mainline tunnels, ramps, and connecting roadway.

Area Geotechnical Consultant (AGC): The AGC contract for the Fort Point Channel Crossing (G023C) was awarded to the geotechnical firm GZA Environmental (GZA) on October 18, 1989 for \$7,015,650. GZA was issued its NTP on November 14, 1989. The geotechnical contract, originally scheduled to be completed June 21, 1994, was completed July 31, 1996 at a cost of \$9,794,620.

The scope of the original AGC contract stated that GZA was responsible for performing boring, sampling, and testing programs, including the management of drilling contractors, and providing recommendations for the Section Design Consultant's use in preparing final design. The scope also included the preparation of geotechnical data and engineering reports. Specifically, GZA was responsible for performing an analysis and making recommendations regarding the methods of excavation support and the criteria for the design of excavation support systems. In addition, where the I-90 cut-and-cover tunnel interfaces with the Fort Point Channel Tunnel tubes, GZA was required to investigate applicable

cofferdam construction concepts. GZA's project work limits included the D009A and D009B design contracts.

Audit Scope, Objectives, and Methodology

Our audit, which is ongoing, included an examination of MHD's management activities associated with the Fort Point Channel design segment of the CA/T Project through December 31, 1999. The objectives of our audit were to determine whether MHD's management activities (a) complied with applicable laws and regulations, and (b) resulted in effective, economical, and efficient utilization of resources. In order to accomplish these objectives, we employed several audit tests and procedures during our examination. We reviewed applicable laws, regulations, and internal operating policies and procedures; interviewed project personnel; and toured project sites. In addition, we reviewed contracts, invoices, cost records, correspondence files, and other documents, as determined necessary. Our examination was made in accordance with applicable generally accepted government auditing standards for performance audits.

AUDIT RESULTS

Inadequate Management Oversight over the Design of the Fort Point Channel Crossing Resulted in Additional Project Costs of More Than \$19 Million

The Fort Point Channel Crossing in South Boston, an area underlain with soft clays, involves the design and construction of a series of multi-lane highway tunnels under the South Station railroad tracks, over the Massachusetts Bay Transportation Authority's (MBTA) Red Line and in between the United States Postal Annex and the Gillette Company.

The design of the Fort Point Channel Crossing was impacted by the Massachusetts Highway Department's (MHD) inability to resolve in a timely manner the following two significant issues: the extended debate regarding the circular cofferdam preliminary design and the delay in resolving Ramp L design problems.

Due to the significant increases in construction cost and schedule estimates associated with the temporary support of excavation, MHD management established a Cost Recovery Committee (CRC) to determine whether any deficient design performance had occurred. Although the CRC concluded that there was no justification to pursue cost recovery, several delays occurred. We estimate that the design delays increased construction costs by approximately \$13 million. In addition, the Central Artery/Third Harbor Tunnel (CA/T) project incurred redesign costs of \$6.4 million.

a. **Extended Debate Regarding the Circular Cofferdam Preliminary Design:** Under the terms of its management contract, Bechtel/Parsons Brinckerhoff (B/PB) was responsible for developing the preliminary design for the Central Artery, including the Fort Point Channel Crossing. In its preliminary design of the Fort Point Channel Crossing, B/PB proposed using a series of 50-foot diameter cellular cofferdams as a temporary support of excavation for the west-bank interface of the land and water tunnel tubes, which would permit the interface to be constructed in a dry environment.

The area geotechnical consultant (AGC) contract for the Fort Point Channel Crossing (G023C) was awarded to the geotechnical firm, GZA Environmental (GZA) on October 18, 1989 with a Notice to

Proceed (NTP) on November 14, 1989. The AGC contract included a boring program that would serve to advance the preliminary design of the I-90/I-93 interchange design contract (D009A). A draft geotechnical report was to be provided to B/PB on March 29, 1991. However, the AGC's drilling subcontractors were delayed due to "longer than anticipated contract formation and approval cycles." The geotechnical data was actually provided to B/PB on October 11, 1991.

The scope of the AGC contract required GZA to analyze and recommend the method of excavation support and the criteria for the design of the excavation support systems. Where the I-90 cut-and-cover tunnel interfaced with the Fort Point Channel tunnel tubes, GZA was also required to investigate other applicable cofferdam construction concepts.

GZA first raised the issue of the stability of the cofferdam cells at a June 1991 meeting. GZA stated that there could be problems with the stability of the cofferdams because of the variability of the clay and that it was looking at alternatives. GZA transmitted its Draft Geotechnical Engineering Report to B/PB on October 11, 1991 and reported that the "compromised integrity [of the cellular cofferdam] is compounded by low bearing capacity due to deep clay underlying most of the excavation . . . which presents a high risk of instability." GZA proposed the construction of a gravity retaining wall around the perimeter of the excavation in the channel.

On November 4, 1991, B/PB rejected GZA's Draft Engineering Report, stating that the report contained an alternative cofferdam design that deviated from the preliminary design prepared by B/PB. GZA was directed to delete all references and discussions of alternative cofferdam designs. This statement to GZA is confusing in light of the fact that GZA was required by its contract to investigate "other applicable cofferdam construction concepts." B/PB requested that cofferdam alternatives not be raised in GZA's engineering report because "the purpose of the geotechnical reports is to provide all geotechnical data and information to the Section Design Consultants (SDCs) to enable them to complete final design based on only the preliminary design provided by B/PB."

Concurrent with GZA's concerns regarding the stability of the cofferdam preliminary design, the CA/T project solicited proposals from prospective SDCs for the D009A design contract. In its January 1991 technical proposal, Maguire/Harris, the eventual D009A SDC responsible for developing final design, also raised concerns about the cellular cofferdam concept due to the existence of soft soils and underlying clay in the Fort Point Channel. Maguire/Harris's technical proposal stated that the presence of these soils would present serious stability problems for the cellular cofferdam but could be overcome by using alternative cofferdam designs.

According to the D009A design contract, B/PB was to provide Maguire/Harris with a copy of GZA's Draft Engineering Report. On January 3, 1992, Maguire/Harris notified the CA/T Project that it had not received GZA's Draft Geotechnical Report and stated that "it behooves all involved with the D009A project to make more geotechnical data and information available by undertaking supplemental borings."

On January 21, 1992, Maguire/Harris submitted its review comments on B/PB's preliminary design of the I-93/I-90 interchange. Maguire/Harris concluded that there was a major lack of geotechnical information and that B/PB's design was not at the 25% preliminary design stage. According to project officials, preliminary design should be at the 25% level before undertaking final design. Maguire/Harris stated that "due to the fact that a major part of the information is not available, we conclude that the preliminary design at this time is not at the 25% level of completion." Maguire/Harris informed CA/T Project officials that GZA's Draft Geotechnical Engineering Report supporting the preliminary design of the cellular cofferdams had not been provided. Maguire/Harris cautioned that the construction of cellular cofferdams could be difficult to achieve and could be technically not possible due to geotechnical stability issues and recommended that B/PB's preliminary cellular cofferdam design be replaced by internally braced rectangular cofferdams. Although Maguire/Harris received a portion of GZA's Draft Geotechnical Engineering Report on January 27, 1992, B/PB did not furnish the critical section of the report concerning the excavation support system because GZA was in the process of revising it at B/PB's direction to conform with B/PB's preliminary design.

In March 1992, Maguire/Harris submitted a report to B/PB for an alternate cofferdam design using braced cofferdams and compared the costs, advantages, and disadvantages of the preliminary design and alternative design. After reviewing the Maguire/Harris proposal, a senior staff engineer of B/PB's design review committee noted that the internally braced cofferdams were preferable to the "clumsy cellular cofferdams that were proposed in B/PB's preliminary design." The design review committee engineer stated that:

Final cost of the internally braced cofferdam will probably exceed the [cost of] the cellular cofferdam. But at least the internally braced cofferdams can be made to work.

However, on April 17, 1992, B/PB rejected that alternative because it did not address bottom stability of the cofferdam cells and would not save construction time. In addition, B/PB stated that:

As with any design there is more than one solution, however, at this time we do not believe that the [9A SDC] has proven either that the cellular cofferdams will not work, or that the braced cofferdam is superior to the cellular cofferdam. At the same time, we are reviewing our original cellular cofferdam design in order to address some of the concerns that you mentioned and verify that it remains a feasible, or even preferred, scheme.

On April 27, 1992, B/PB issued its response to the Maguire/Harris comments on the preliminary design for the D009A design contract. At one point in the response, B/PB acknowledged that it and GZA recognized potential problems with the cellular cofferdam concept and that GZA would recommend alternative cofferdam construction where soil stability is a problem. However, in the same correspondence, B/PB stated that the only recommended excavation support system in the Fort Point Channel is a circular cofferdam and directed Maguire/Harris to "restrain their engineering instinct to pursue design revisions and concentrate their energy on solving the problems provided by the Preliminary Design." In the absence of any reliable geotechnical data to the contrary, Maguire/Harris continued to express concerns about the cellular cofferdam design proposed by B/PB. Finally Maguire/Harris received the Final Draft Geotechnical Engineering Report from the project at the end of May 1992, more than six months after the SDC's NTP and nine months after B/PB received the draft report from GZA.

On June 19, 1992, Maguire/Harris' own geotechnical subconsultant, Haley and Aldrich, warned that B/PB's cellular cofferdam calculations would not provide a stable excavation support system within the Fort

Point Channel excavation. Haley and Aldrich recommended using internally braced cofferdams and channelization² of the Fort Point Channel and advised B/PB that an enhanced cellular cofferdam system would be very expensive and time consuming.

On June 23, 1992, Maguire/Harris informed B/PB that the cofferdam design for Fort Point Channel had to be resolved in order to maintain both the current D009A design schedule and the CA/T Project's master construction schedule. Maguire/Harris claimed that the six-month delay in receipt of GZA's Geotechnical Engineering Report and the lack of geotechnical information prohibited further design development. In the absence of this information, Maguire/Harris stated that the current cofferdam design must be "enhanced" in order to overcome stability that would significantly increase the project's construction cost estimate.

Despite repeated warnings from GZA, Maguire/Harris, and Haley and Aldrich that B/PB's preliminary cellular cofferdam design would not work without significant and costly enhancements, it was not until August 1992, more than 18 months after Maguire/Harris's technical proposal raised the issue of cofferdam stability, that B/PB finally abandoned the preliminary cofferdam design and directed Maguire/Harris to develop alternative excavation support systems. According to an independent consultant's study of the issue, approximately six of the 18-month design development period was unproductive because the management consultant "was reluctant to consider the weaknesses of the cellular cofferdam approach and resisted giving due consideration to the consultants' [GZA, Maguire/Harris and Haley and Aldrich] concerns." The delay in resolving the cofferdam issue not only adversely affected the D009A design contract, but also the CA/T Project's need to adjust the project's master schedule.

In commenting on the problems associated with the original circular cofferdam design, a Federal Highway Administration (FHWA) memorandum, dated June 20, 1994, noted that, despite the limited geotechnical information, "no elevated attention was placed on the temporary support of excavation system."

² Channelization would temporarily divert the flow of water in Fort Point Channel away from the construction work

b. Delay in Resolving Ramp L Design Problems: Under B/PB's preliminary design, Ramp L (which spanned several design packages including D009A) would carry exiting traffic from I-93 and merge it with I-90 traffic as a left-hand entry continuing towards the Third Harbor Tunnel. In the D009A design contract, Ramp L was to be built on land beside the Fort Point Channel. According to the FHWA the left-hand entrance of Ramp L forced an undesirable two-sided weave that jeopardized the safety of the traffic further down I-90.

In November 1990, a year before the D009A design contract was issued, FHWA recommended, among other things, that MHD switch the location of Ramp L, which would result in substantial cost savings and operational improvements. The switch would provide for a right-hand entrance of Ramp L onto I-90. On January 14, 1991 the project rejected FHWA concerns by stating that "we do not feel that the potential benefits of the FHWA scheme warrant the time and resource commitment necessary to perform a more in-depth analysis." In late January 1991, FHWA again expressed concern regarding the left-hand entry of Ramp L onto the I-90 Interchange.

On December 31, 1991 and March 18, 1992, MHD submitted the adjacent 1A and D009B design packages, respectively, to FHWA for its comment and approval. FHWA, MHD, and B/PB officials met on May 21, 1992 to discuss the outstanding design issues for the 1A design contract that included the "two-sided weave" issue with no resolution.

On July 27, 1992 a meeting was held between FHWA, MHD, and B/PB officials to discuss outstanding design issues for the 9B design contract. FHWA again stated that "the left-hand entrance of Ramp L forced an undesirable two-sided weave" that compromised the safety of the traffic further down I-90. FHWA stated that AASHTO³ "clearly and strongly recommends against the use of left-hand entrances" because they are "contrary to driver expectancy" and "extreme care should be exercised to avoid left-hand entrances in the

site and reduce the hydrostatic forces on the excavation support system.

³ The American Association of State Highway and Transportation Officials.

design of interchanges.” In August 1992, FHWA again forwarded its concerns regarding the Ramp L alignment to the project.

Finally, on October 2, 1992, B/PB provided MHD with a revised alignment of Ramp L, referred to as Option 14. Due to the significant overlap of the D001A and D009B design packages, B/PB addressed the Ramp L alignment simultaneously. Although B/PB stated that the new scheme would address FHWA concerns, Option 14 had some adverse impacts, namely significant redesign of several design packages. In addition, Option 14 created significant schedule impacts, particularly to the opening of I-90, which at that time was scheduled for 1998. B/PB recommended against adopting Option 14 because of the schedule impact to the I-90 opening and that it complicated matters by moving the construction of Ramp L into the waters of Fort Point Channel.

Despite B/PB's objections, MHD adopted Option 14 and issued several change orders that directed Maguire/Harris and other section design consultants to suspend design work associated with the I-90 tunnels. B/PB was required to provide a revised alignment and profiles to Maguire/Harris by January 1, 1993. The revised alignment would serve as the basis for Maguire/Harris to develop a new preliminary design. In February 1993 Haley and Aldrich warned that further geotechnical studies for the temporary excavation support system within Fort Point Channel had been delayed due to the prolonged resolution of the Ramp L realignment. B/PB provided Maguire/Harris with the revised profile on May 28, 1993, five months later than scheduled. Subsequently, on June 28, 1993 Maguire/Harris submitted its design cost proposal for the revised Ramp L alignment. On August 1993, B/PB issued the NTP for Maguire/Harris to proceed with final design.

As a result, from November 1990 when FHWA first raised the issue of a left-hand entry onto I-90 until it was resolved in August 1993, 34 months had elapsed. Proceeding to final design prior to resolving significant outstanding design issues presents the inherent risk of having to later face additional redesign costs and schedule delays should major design changes be made. About \$6.4 million in redesign costs could have been avoided had MHD and its management consultant resolved FHWA comments regarding Ramp L in a timely manner. Moreover, the five-month delay in providing a new alignment not

only adversely affected the D009A design contract, it also impacted several follow-on construction contracts. This delay, in part, required the CA/T project to adjust the master schedule.

Later Development Involving the Fort Point Channel Crossing: Due to the ever-increasing complexity, size, and cost of the I-90/I-93 interchange construction contract, it was decided to split the construction contract into two contracts: Marine Construction (CO9A1) and Land Construction (CO9A4). The split would allow the D009A SDC to concentrate on the early marine construction work.

As the D009A-design progressed, a B/PB memorandum dated April 26, 1994, estimated the D009A construction support of excavation cost would significantly increase to approximately \$1.2 billion. As a result, on June 7, 1994, B/PB directed Maguire/Harris to again slow down design work while the cost increases were being evaluated. On July 21, 1994, B/PB issued a change order that directed Maguire/Harris to suspend all design work associated with the CO9A1 and CO9A4 construction contracts. Similarly, B/PB directed the D001A, D009B and D009C SDCs to suspend design on certain portions of the interchange.

On December 9, 1994, B/PB, in an attempt to resolve the excavation support problem, added a new construction contract to the D009A design contract, Fort Point Channel Excavation Support (CO9A7). In order to overcome the instability of the soil problem, the D009A SDC developed a design for the CO9A7 construction contract that used a deep soil mix (DSM) technology. DSM injects grout into the underlying soil in order to stabilize it to sufficient strength to support the eventual construction of a temporary excavation support system. Finally, on February 7, 1995, the CA/T Project issued another change order to implement the Extended Immersed Tube Tunnel (EITT) design concept. The EITT concept involves increasing the number of tunnel tube sections from the original two to six. The tunnel tubes would be placed further in-land to avoid having to construct large and costly cofferdams.

As a result of the mounting schedule impacts involving the Fort Point Channel and other project areas, the project issued a revised project master schedule (Revision 6) on March 1, 1995. Revision 6 changed the opening of I-90 roadway from 1998 until December 2001.

Cost Recovery Review: In August 1994, MHD established a CRC to review whether sufficient basis existed to pursue recovery of costs or damages the Commonwealth had incurred or would incur because of deficient performance by design professionals in connection with the CA/T project. The CRC members included MHD's Director of Engineering, MHD's Director of Construction, and FHWA's Project Engineer. As part of this process, an outside consultant was contracted to review the Fort Point Channel issue. The consultant reported that a reasonable standard of care had not been compromised, although several unnecessary delays had occurred. Based on this report, the CRC notified the Project Director that there was no opportunity to pursue cost recovery. Because the consultant was charged with reviewing design performance, we were informed that the consultant's report did not address the impact that the unnecessary design delays had on project construction costs due to inflation. We estimate that the unnecessary design delays increased construction costs costs due to inflation by approximately \$13 million.

The above delays contributed significantly to the slippage in the project's master schedule for the I-90 opening. If the CA/T Project had resolved the repeated geotechnical concerns expressed by the design professionals in a timely manner as well as FHWA's concerns regarding Ramp L, a minimum of \$6.4 million in redesign costs and approximately \$13 million in increased construction costs due to inflation could have been avoided.

Recommendation: Because of the significant increased costs associated with design slow-downs, work stoppages, and redesign efforts, project management and the cognizant state agency should ensure that significant design issues have been resolved before undertaking final design activity in the impacted area. In addition, due to the increased construction costs due to inflation associated with construction delays, MHD project management should increase its oversight of the design process so as to preclude the untimely resolution of design conflicts.

Auditee's Response: In his comments to a draft of this report, the Deputy Project Director stated that:

In the Fort Point Channel area, I-90 tunnels must run under active railroad tracks, between New England's largest mail sorting facility and Gillette's world manufacturing headquarters, under the channel and above the Massachusetts Bay Transportation Authority's Red Line subway tunnel. Traffic must continue to move on I-93, the South Bay Interchange with the Massachusetts Turnpike, and on the rail lines to and from South Station. Crossing under the tracks and the channel requires techniques -- tunnel jacking and concrete immersed tubes -- which have not previously been used in North America.

Further complicating construction in the channel is the soil along and beneath the waterway, which led to some of the design issues covered in your report. Your report does not, however, consider the context in which these design issues were resolved. The fast-track process used on the Central Artery project -- in which construction starts in some areas before design is finished in others -- inherently involves design changes as contracts are coordinated and actual field conditions encountered during construction. The alternative -- waiting for all designs to be complete before starting construction -- would be dramatically more expensive and could not eliminate changed conditions in the field.

Solving design challenges in a site of this complexity requires a meticulous, iterative process that can be time-consuming. It is crucial to grasp the unprecedented complexity and inter-relatedness of Central Artery construction before drawing conclusions about these design decisions. In the Fort Point Channel area, some of the finest design and construction minds in the world met formidable challenges without increasing the total project budget. In the end, no unnecessary expenses have been incurred in the Fort Point Channel crossing. The crossing as it is being built costs essentially what it would have cost had all conditions been known from the outset.

Auditor's Reply: We disagree with the Deputy Project Director's comment that our report does not consider the context in which the design issues discussed in the report were resolved. Moreover, our report does not recommend that the project delay construction until all the designs are complete. On the contrary, as discussed in the specific comments below, the focus of our report is the resolution of critical design issues that need to be resolved timely notwithstanding whether a fast track or alternate process is used by the Project.

As discussed in the body of this report and in the following specific comments, the cofferdam and Ramp L delays contributed to the unnecessary revision of designs and the need for the Project to revise its master schedule completion date by several years. Such delays cause construction cost increases due to inflation. Whether the Project absorbs the increase through cost containment initiatives or by reducing Project scope, does not alter the fact that the Project could have done those same things in addition to correcting the problems identified in the report, thus realizing the recommended benefits as well.

Auditee's Response Relative to the Channel Crossing:

The six months of "delay" cited in your report prudently allowed design issues to be resolved before proceeding full speed. The conceptual design for the Fort Point Channel crossing was based on conventional engineering ideas for working in water, using cofferdams to provide a dry work area. The Project responsibly resisted changing the cofferdam model, since change is disruptive and potentially costly given the need to coordinate with adjacent contracts. A full crossing using concrete immersed tubes was not initially considered because it would have been more expensive than the conventional cofferdam approach. But the issue in the channel was excavation support, and the design process revealed that the cost of alternate cofferdam options would have added \$500 million to the cost of the channel crossing.

Your \$13 million escalation estimate . . . is unexplained in your report. . . . The Fort Point Channel work was redesigned to meet the overall Project construction milestones so that there are no cost increases from delay. Indeed the design changes reduced cost increases for the channel crossing by \$300 million. The remaining increase was absorbed through cost containment elsewhere on the Project, with no net change to the \$10.8 billion Project budget.

Incidentally, the deep soil mix solution to the soil instability problem in the Fort Point Channel drew on the Project's success with the technique in East Boston, where soil mixing was used on the Ted Williams Tunnel. Deep soil mixing had never been used before at this latitude and was not considered a viable alternative during early design. By expanding the state of the art in East Boston we were able to develop a new option to solve the greater difficulties in the channel.

Auditor's Reply: Relative to the first point, our concern is not with the solution to the problem, but rather with the lengthy period of time it took the Project to address the problem. This is especially troublesome since the key parties involved had been vocalizing their concerns to the Project for some time. The unnecessary delay is further evidenced by the independent consultant hired by the project to review the Fort Point Channel issue. The independent consultant concluded that the management consultant "was reluctant to consider the weaknesses of the cellular cofferdam approach and resisted giving due consideration to the consultant's concerns." This lack of facilitation unnecessarily extended the design process by 6 months.

Regarding the second point, as discussed in our report, the delay in resolving the cofferdam and Ramp L issues required the Project to adjust its master schedule. Using the Project determined construction inflation rates, we estimate the 11 month delay impacted the Project costs by about \$13

million. We take no issue with the Project's statement that revised design changes and cost containment initiatives reduced Project costs. Such changes could have been realized independent of the unnecessary delays identified in this report.

Regarding the third point, we commend the Project's use of soil mix technology to the Fort Point Channel area.

Auditee's Response Relative to Ramp L: In commenting on this issue, the Deputy Project Director advised us that:

The same fast-track reasoning applies to the \$6 million in purported redesign costs on the Ramp L change, which was made at the request of the Federal Highway Administration. The original ramp design met applicable highway standards and minimized environmental damage in the channel. We resisted change based on unpredictable schedule impacts that could follow a reopening of environmental reviews. In the end, we produced an environmentally acceptable design that was consistent with Federal Highway's concerns for the ramp's configuration. When change is required, as it was in these two cases, the cost of implementation is far less than the cost of waiting until all design issues are resolved to start work.

Auditor's Reply: Although we appreciate the Project's concern that changes can be disruptive and costly, the focus of our report is on the timeliness of the solutions. This is evidenced by the 5-month delay that was the result of the management consultant's failure to deliver a new alignment on time.

Auditee's Response Relative to Cost Recovery: In commenting on this issue, the Deputy Project Director advised us that:

You note that a Cost Recovery Committee found no reason to seek recovery of costs from any party involved in these issues, in spite of delays. The outside consultant you cited regarding inordinate time to resolve design questions also suggested that extended time and delayed decisions may have saved the Project money by preventing unnecessary design work. The consultant also concluded, "all parties performed with a reasonable standard of care with respect to this very complicated and unique design challenge."

Auditor's Reply: As noted in our report, the consultant reported that a reasonable standard of care had not been compromised, although several unnecessary delays had occurred. Because the consultant was charged with reviewing design performance, we were advised that the consultant's report did not address the impact that the unnecessary design delay had on Project construction costs due to inflation. The independent consultant was unable to support the statement that the extended design time and

delayed decisions may have saved time. As noted above, we estimate the increased construction cost due to inflation to be about \$13 million.

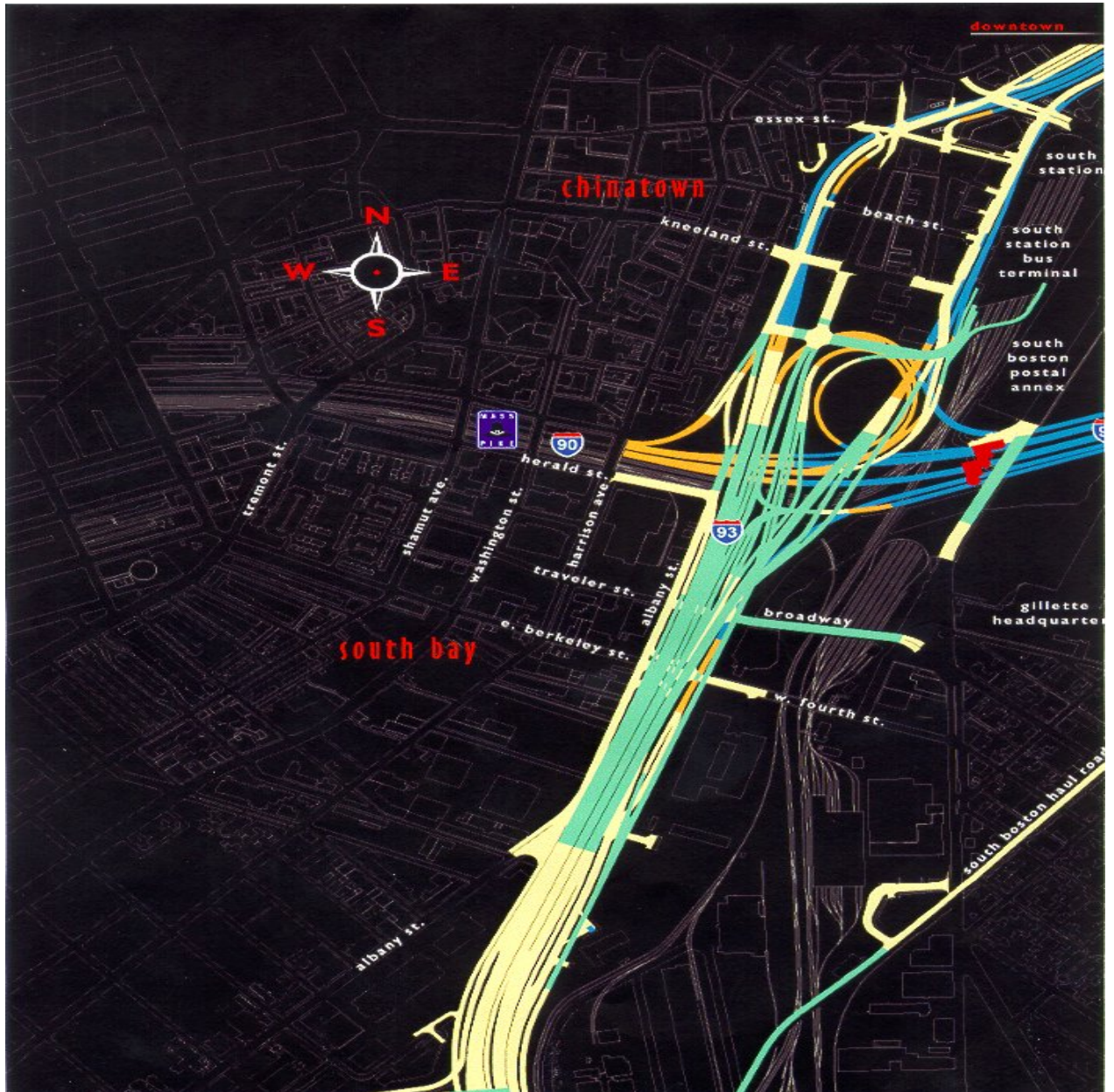
APPENDIX A

CENTRAL ARTERY/TUNNEL PROJECT – MAP AT COMPLETION



APPENDIX B

CENTRAL ARTERY/TUNNEL PROJECT – MAP OF SOUTH BAY



APPENDIX C

CENTRAL ARTERY/TUNNEL PROJECT PHOTO – FORT POINT CHANNEL LOOKING EAST



APPENDIX D

CENTRAL ARTERY/TUNNEL PROJECT PHOTO – OVERLOOKING CASTING BASIN



APPENDIX E

CENTRAL ARTERY/TUNNEL PROJECT PHOTO – OVERLOOKING FORT POINT CHANNEL

